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THE NEW LIGHT AND THE NEW PHOTOGRAPHY

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Early Work on Invisible Rays.

Notes by E. J. WALL, F.R.P.S.

THAT force which we call light is not a tangible entity which we can lay hold of like a piece of wood, it is a very rapid wave motion or vibration of a hypothetical medium called the luminiferous ether, which motion communicated to the retina of the eye gives rise to a sensation which we call light.

We are accustomed to speak of substances as being opaque, translucent, or transparent, but these terms are not absolute by any means, as will be seen from the following statement. A sheet of gold of (say) one-eighth of an inch thickness appears to us to be opaque, that is, we cannot see through it; ordinary glass, on the other hand, we can see through; but reduce the gold to a thin leaf by rolling and hammering, and it allows light to pass through: increase your glass to a very great thickness and it becomes absolutely opaque, or allows no light to pass.

We talk of daylight as white light, but if a narrow slice of daylight be allowed to fall upon a triangular shaped piece of glass, called a prism, we obtain a band of colors, ranging from a deep crimson red, through orange, yellow, green, blue, to violet, which band is called the spectrum. When sun or daylight is examined in this way, it is found to be crossed by numerous transverse dark lines which may be popularly described as landmarks or milestones. Of such a comparatively finite nature is our sight or brain, that we can only discern a very small portion of the spectrum; that is to say, as long as the vibratory motion lies within certain limits, we are sensible of the same as light, but at either end beyond these limits stretch fields utterly beyond our visual sensations, but which can be detected by other means, such as photography.

In fig. 3 we have the reproduction of a photogram of the spectrum, kindly lent for the purpose by Mr. J. W. Gifford. In this, the only portion which can be seen by us is that lying between A and H, but that there are vibrations or waves far beyond this origin is shown by photography, and in this region beyond H, or the violet, it stretches at least nine or ten times as far, how much further we cannot say. If we turn to the other end, the red, we find in the infra or invisible red region an extension fourteen times the length of the visible spectrum, as seen in figs. 1 & 2, reproduced from a result obtained by Professor Langley, of the Smithsonian Institute of America.

Many will, doubtless, also remember the experiment made by the late Professor Tyndall, in his most popular lectures at the Royal Institution, in which he concentrated the invisible red rays from an electric lantern, and in their focus fused and burnt many metals. Captain Abney also photographed, in an absolutely dark room, a kettle of boiling water, by the same infra red rays.

The close connection between light and electricity has long been known, for Clerk Maxwell enunciated the theory that light itself is but an electro-magnetic phenomenon, and that which we call waves of light are not mechanical waves at all, but are immensely rapid electric displacements taking place in the all-pervading ether of space; and Professor Sylvanus Thompson states as his opinion, that with further developments of the theory it would be found to satisfactorily explain all the phenomena of light; and that electricity generates light or vibratory wave motion is, of course, common knowledge, and that electricity is itself but a wave-like motion has been shown by the classic experiments of Hertz, who proved still further the similarity of electricity to light by reflecting and refracting the waves of electricity he generated just as though they were light waves.

We cannot see electricity, nor can we see the ultra-violet and infra-red rays, but we can prove the existence of the same by very easy experiments; in the case of electricity, the famous researches of Hertz have placed the existence of these electrical waves beyond doubt; the existence of the infra-red light waves has been proved not only by photography, but also by Prof. Langley's Bolometer, and the results obtained by this as well as by photography in the ultra violet are shown in figs. 2 and 3.

The Bolometer devised and used by Professor Langley consists of an instrument for measuring minute differences of radiant heat by changes in the electric resistance of a blackened conductor exposed to it. It consists of a series of plates of metal connected with a battery and galvanometer, to the latter being attached a very minute concave mirror, on to which is thrown a narrow pencil of light. When the spectrum falls upon the blackened surface connected with the metal plates the electric resistance is changed, the galvanometer deflected, and the spot of light reflected from the concave mirror, which is hung upon a very fine quartz fibre, is received upon a photographic plate, and on development, a figure like the chain of mountains shown in fig. 1, above the spectrum is obtained, from which the line spectrum (called a bolograph) is constructed. The theory being that where the infra red spectrum falls there is a development of heat, but where the Frauenhofer lines occur there is no heat, and therefore a deflection of the spot of light. With the Bolometer it is possible to measure a difference of heat of one hundred-thousandth of a degree of Fahrenheit's thermometer scale.

Besides, however, these waves or rays, there are others directly connected with the phenomena of electricity which become distinctly visible under certain conditions. If we take a glass tube and pass a wire through each end and close the ends up, and then draw off by a fine aperture the air so as to leave, as far as we can, very little or no air

remaining, or as it is technically called, form a vacuum, we have what is known as a Crookes' tube; and on passing a current of electricity through this, we obtain some striking phenomena; for instance, from the anode or positive pole of the battery, induction coil or Wimshurst machine supplying the current, we have a series of beautiful "striations" or "striæ" of light, which vary in color with the gas, a small residuum of which remains in the tube. These however, have but little interest to us. From the cathode or negative pole, proceeds a stream of light or glow which has some extraordinary properties, and has received the name of "cathode rays." In the first place, these cathode rays cause the most brilliant phosphoresence even in glass, but on certain well-known chemical products the light is extremely brilliant, and it is possible, by the interposition of screens or patterns cut to particular shape, to obtain sharp clear-cut shadows of the patterns. Further than that, if a series of light vanes or paddles be mounted on an axis inside one of these tubes, they will rapidly rotate like the well-known radiometer or light mill. Then again, these cathode rays have the property of passing through thin metallic foil in an absolutely straight line, and exciting fluorescence when allowed to fall upon paper saturated with various chemicals, such as pentadecylparatolylketone or platino-cyanide of barium. Herr Lenard, of Hungary, examined these rays in 1894, and conducted numerous experiments, and by placing the ordinary photographic plate and sensitive paper behind various substances, such as aluminium, wood, quartz, etc., he was able to obtain shadow images or photographs, so-called, showing the permeability of these substances to these rays.

On applying an ordinary magnet to these rays, it was found that they were deflected or attracted by the magnet. Practically then we have come back to one of our first statements, namely, that the terms opaque, translucent, and transparent, are but relative; they are practically interchangeable under certain conditions, for quartz which is quite transparent to ordinary light, is absolutely opaque to these rays; and aluminium and cardboard of such a thickness as to be opaque to ordinary light, were transparent or translucent to these rays.

But a week or two ago, we were startled by the statement emanating from a journalist in Vienna, that Professor W. K. Röntgen, of Würzburg, had been able to photograph through wood, paper, leather, and human flesh, and that it would be possible, for instance, to photograph the structure of a person's body through his or her clothes. Naturally this gave rise to considerable incredulity and fun at the expense of the learned professor, and even some of our shining lights in the scientific world were not loth to show their erudition by discounting the discovery, and ascribing the effects to the well-known ultra-violet rays and the electric waves of Hertz. It will be well therefore to hear what Professor Röntgen has to say himself, and by the kindness of the translator and of the editor of *Nature*, we are able to give in full the original paper.

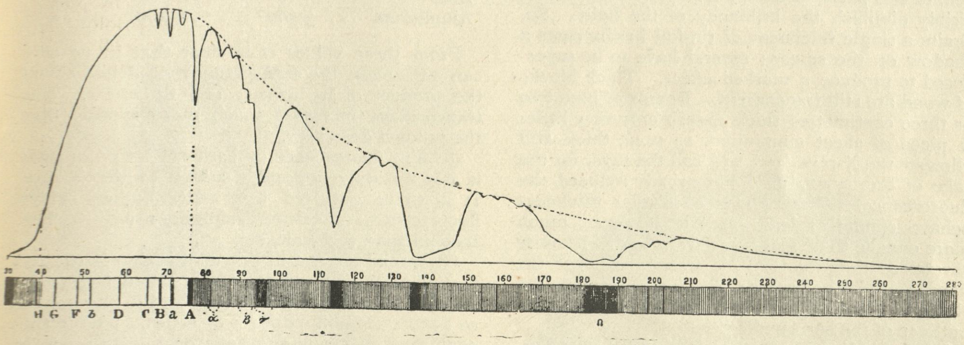

FIG. 1.—Langley's Normal Bolometric Spectrum, showing curves of galvanometer deflections.

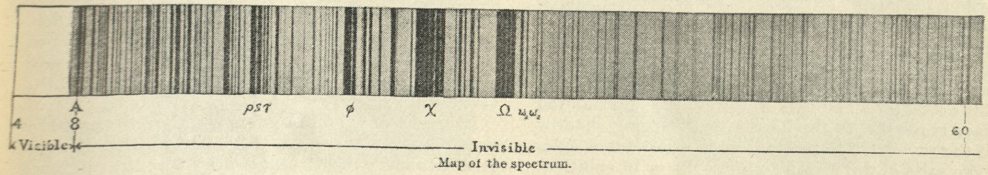

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FIG. 2—Langley's latest Spectrum. The white portion on the left is the visible Spectrum, the shaded portion on the right representing the invisible or infra red.

On a New Kind of Rays.

By W. K. RÖNTGEN.

Translated by ARTHUR STANTON from the *Sitzungsberichte der Würzburger Physik-medic, Gesellschaft*, 1895.
Reprinted from *Nature*, Jan 23, '96, p. 274.

(1) A discharge from a large induction coil is passed through a Hittorf's vacuum tube, or through a well-exhausted Crookes' or Lenard's tube. The tube is surrounded by a fairly close-fitting shield of black paper; it is then possible to see, in a completely darkened room, that paper covered on one side with barium platino-cyanide lights up with brilliant fluorescence when brought into the neighborhood of the tube, whether the painted side or the other be turned towards the tube. The fluoresence is still visible at two metres distance. It is easy to show that the origin of the fluorescence lies within the vacuum tube.

(2) It is seen, therefore, that some agent is capable of penetrating black cardboard which is quite opaque to ultra-violet light, sunlight, or arc-light. It is therefore of interest to investigate how far other bodies can be penetrated by the same agent. It is readily shown that all bodies possess this same transparency, but in very varying degrees. For example, paper is very transparent; the fluorescent screen will light up when placed behind a book of a thousand pages; printer's ink offers no marked resistance. Similarly the fluorescence shows behind two packs of cards; a single card does not visibly diminish the brilliancy of the light. So, again, a single thickness of tin-foil hardly casts a shadow on the screen; several have to be superposed to produce a marked effect. Thick blocks of wood are still transparent. Boards of pine two or three centimetres thick absorb only very little. A piece of sheet aluminium, 15 m.m. thick, still allowed the X-rays (as I will call the rays, for the sake of brevity) to pass, but greatly reduced the fluorescence. Glass plates of similar thickness behave similarly; lead glass is, however, much more opaque than glass free from lead. Ebonite several centimetres thick, is transparent. If the hand be held before the fluorescent screen, the shadow shows the bones darkly, with only faint outlines of the surrounding tissues.

Water and several other fluids are very transparent. Hydrogen is not markedly more permeable than air. Plates of copper, silver, lead, gold, and platinum also allow the rays to pass, but only when the metal is thin. Platinum ·2 mm. thick allows some rays to pass; silver and copper are more transparent. Lead 1·5 mm. thick is practically opaque. If a square rod of wood 20 mm. in the side be painted on one face with white lead, it casts little shadow when it is so turned that the painted face is parallel to the X-rays, but a strong shadow if the rays have to pass through the painted side. The salts of the metals, either solid or in solution, behave generally as the metals themselves.

(3) The preceding experiments lead to the conclusion that the density of the bodies is the property whose variation mainly affects their permeability. At least, no other property seems so marked in this connection. But that the density alone does not determine the transparency, is shown by an experiment wherein plates of similar thickness of Iceland spar, glass, aluminium, and quartz were employed as screens. Then the Iceland spar showed itself much less transparent than the other bodies, though of approximately the same density. I have not remarked any strong fluorescence of Iceland spar compared with glass (see below, No. 4).

(4) Increasing thickness increases the hindrance offered to the rays by all bodies. A picture has been impressed on a photographic plate of a number of superposed layers of tinfoil, like steps, presenting thus a regularly increasing thickness. This is to be submitted to photometric processes when a suitable instrument is available.

(5) Pieces of platinum, lead, zinc, and aluminium foil were so arranged as to produce the same weakening of the effect. The annexed table shows the relative thickness and density of the equivalent sheets of metal.

	Thickness.	Relative Thickness.	Density.
Platinum ..	·018 mm. ..	1 ..	21·5
Lead	·050 ,, ..	3 ..	11·3
Zinc	·100 ,, ..	6 ..	7·1
Aluminium ..	3·500 ,, ..	200 ..	2·6

From these values it is clear that in no case can we obtain the transparency of a body from the product of its density and thickness. The transparency increases much more rapidly than the product decreases.

(6) The fluorescence of barium platino-cyanide is not the only noticeable action of the X-rays. It is to be observed that other bodies exhibit fluorescence, *e.g.* calcium sulphide, uranium glass, Iceland spar, rock-salt, etc.

Of special interest in this connection is the fact that photographic dry plates are sensitive to the X-rays. It is thus possible to exhibit the phenomena so as to exclude the danger of error. I have thus confirmed many observations originally made by eye observation with the fluorescent screen. Here the power of the X-rays to pass through wood or cardboard becomes useful. The photographic plate can be exposed to the action without removal of the shutter of the dark slide or other protecting case, so that the experiment need not be conducted in darkness. Manifestly, unexposed plates must not be left in their box near the vacuum tube.

It seems now questionable whether the impression on the plate is a direct effect of the X-rays, or a secondary result induced by the fluorescence of the material of the plate. Films can receive the impression as well as ordinary dry plates.

I have not been able to show experimentally that the X-rays give rise to any calorific effects. These, however, may be assumed, for the phenomena of fluorescence show that the X-rays are capable of transformation. It is also certain

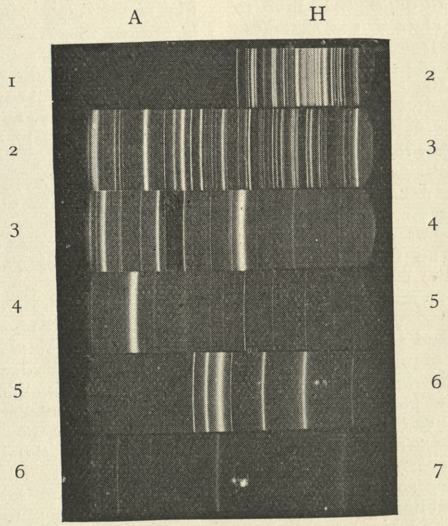

FIG. 3.—Spectrogram. The visible spectrum extends from A to H; the invisible, ultra violet, lies beyond H, and for convenience has been photographed in strips, which are numbered to show their sequence.

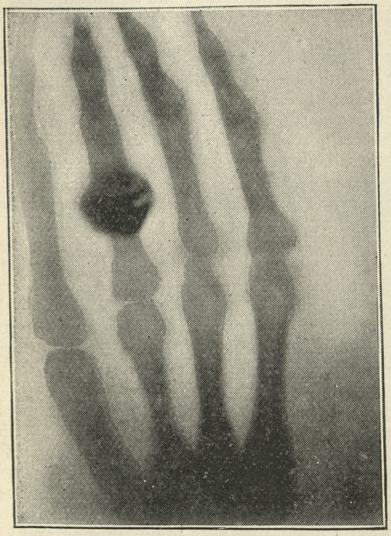

FIG 4.—Shadowgram of the bones in the fingers of a living human hand. The third finger has a ring upon it. (Made by Prof. Röntgen.)

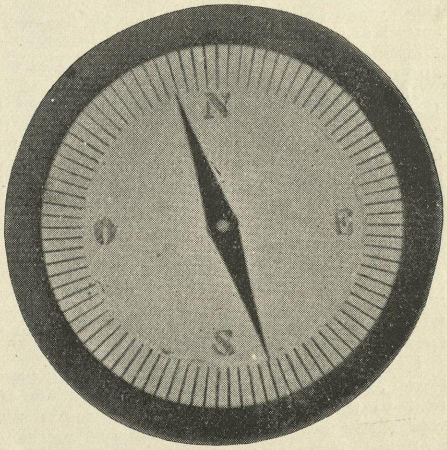

FIG. 5.—Shadowgram of a compass card and needle completely enclosed in a metal case. (Made by Prof. Röntgen.)

that all the X-rays falling on a body do not leave it as such.

The retina of the eye is quite insensitive to these rays: the eye placed close to the apparatus sees nothing. It is clear from the experiments that this is not due to want of permeability on the part of the structures to the eye.

(7) After my experiments on the transparency of increasing thickness of different media, I proceeded to investigate whether the X-rays could be deflected by a prism. Investigations with water and carbon bisulphide in mica prisms of 30° showed no deviation either on the photographic or the fluorescent plate. For comparison, light rays were allowed to fall on the prism as the apparatus was set up for the experiment. They were deviated 10 mm. and 20 mm. respectively in the case of the two prisms.

With prisms of ebonite and aluminium, I have obtained images on the photographic plate, which point to a possible deviation. It is, however, uncertain, and at most would point to a refractive index 1·05. No deviation can be observed by means of the fluorescent screen. Investigations with the heavier metals have not as yet led to any result, because of their small transparency and the consequent enfeebling of the transmitted rays.

On account of the importance of the question it is desirable to try in other ways whether the X-rays are susceptible of refraction. Finely powdered bodies allow in thick layers but little of the incident light to pass through, in consequence of refraction and reflection. In the case of the X-rays, however, such layers of powder are for equal masses of substance equally transparent with the coherent solid itself. Hence we cannot conclude any regular reflection or refraction of the X-rays. The research was conducted by the aid of finely-powdered rock-salt, fine electrolytic silver powder, and zinc dust already many times employed in chemical work. In all these cases the result, whether by the fluorescent screen or the photographic method, indicated no difference in transparency between the powder and the coherent solid.

It is, hence, obvious that lenses cannot be looked upon as capable of concentrating the X-rays; in effect, both an ebonite and a glass lens of large size prove to be without action. The shadow photograph of a round rod is darker in the middle than at the edge; the image of a cylinder filled with a body more transparent than its walls exhibits the middle brighter than the edge.

(8) The preceding experiments, and others which I pass over, point to the rays being incapable of regular reflection. It is, however, well to detail an observation which at first sight seemed to lead to an opposite conclusion.

I exposed a plate, protected by a black paper sheath, to the X-rays, so that the glass side lay next to the vacuum tube. The sensitive film was partly covered with star-shaped pieces of platinum, lead, zinc, and aluminium. On the developed negative the star-shaped impression showed dark under platinum, lead, and, more markedly, under zinc; the aluminium gave no image. It seems, therefore, that these three metals can reflect the X-rays; as, however, another explanation is possible, I repeated the experiment with this only difference, that a film of thin aluminum foil was interposed between the sensitive film and the metal stars. Such an aluminium plate is opaque to ultra-violet rays, but transparent to X-rays. In the result the images appeared as before, this pointing still to the existence of reflection at metal surfaces.

If one considers this observation in connection with others, namely, on transparency of powders, and on the state of the surface not being effective in altering the passage of the X-rays through a body, it leads to the probable conclusion that regular reflection does not exist, but that bodies behave to the X-rays as turbid media to light.

Since I have obtained no evidence of refraction at the surface of different media, it seems probable that the X-rays move with the same velocity in all bodies, and in a medium which penetrates everything, and in which the molecules of bodies are embedded. The molecules obstruct the X-rays, the more effectively as the density of the body concerned is greater.

(9) It seemed possible that the geometrical arrangement of the molecules might affect the action of a body upon the X-rays, so that, for example, Iceland spar might exhibit different phenomena according to the relation of the surface of the plate to the axis of the crystal. Experiments with quartz and Iceland spar on this point lead to a negative result.

(10) It is known that Lenard, in his investigations on cathode rays, has shown that they belong to the ether, and can pass through all bodies. Concerning the X-rays the same may be said.

In his latest work, Lenard has investigated the absorption co-efficients of various bodies for the cathode rays, including air at atmospheric pressure, which gives 4·10, 3·40, 3·10 for 1 cm., according to the degree of exhaustion of the gas in discharge tube. To judge from the nature of the discharge, I have worked at about the same pressure, but occasionally at greater or smaller pressures. I find, using a Weber's photometer, that the intensity of the fluorescent light varies nearly as the inverse square of the distance between screen and discharge tube. This result is obtained from three very consistent sets of observations at distances of 100 and 200 mm. Hence air absorbs the X-rays much less than the cathode rays. This result is in complete agreement with the previously described result, that the fluorescence of the screen can be still observed at two metres from the vacuum tube. In general, other bodies behave like air; they are more transparent for the X-rays than for the cathode rays.

(11) A further distinction, and a noteworthy one, results from the action of a magnet. I have not succeeded in observing any deviation of the X-rays even in very strong magnetic fields.

The deviation of cathode rays by the magnet is one of their peculiar characteristics; it has been observed by Hertz and Lenard, that several kinds of cathode rays exist, which differ by their power of exciting phosphorescence, their susceptibility of absorption, and their deviation by the magnet; but a notable deviation has been observed in all cases which have yet been investigated, and I think such deviation affords a characteristic not to be set aside lightly.

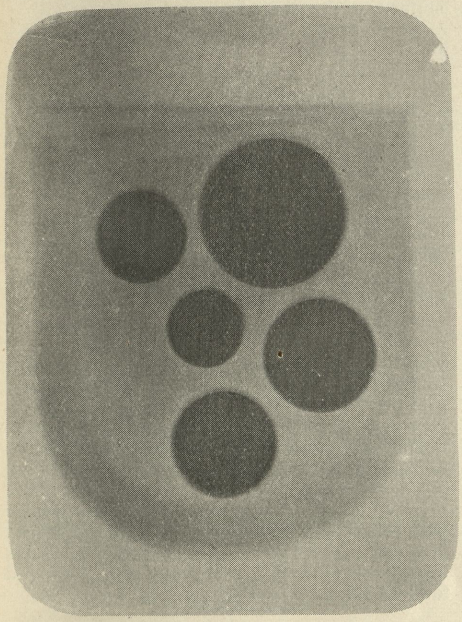

Fig. 6.—Coins inside leather purse. Exposure four minutes.

Fig. 7.—Living frog through sheet of aluminium. Exposure twenty minutes.

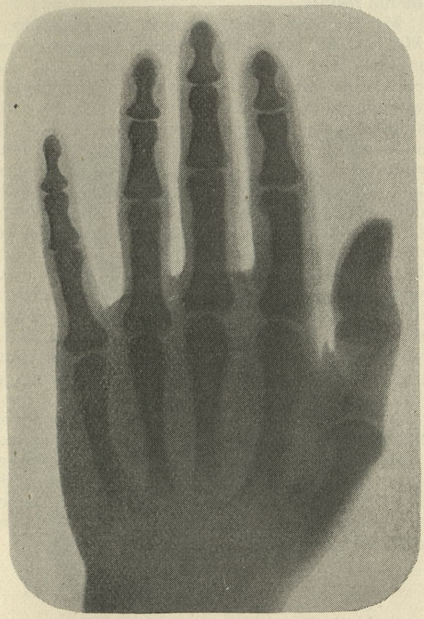

Fig. 8.—Living hand through black vulcanised fibre. Exposure four minutes.

Fig. 9.—Metal objects through calico pocket and sheet of aluminium. Exposure four minutes.

Shadowgrams by Mr. Campbell Swinton.

(12) As the result of many researches, it appears that the place of most brilliant phosphorescence of the walls of the discharge tube is the chief seat whence the X-rays originate and spread in all directions; that is, the X-rays proceed from the front where the cathode rays strike the glass. If one deviates the cathode rays within the tube by means of a magnet, it is seen that the X-rays proceed from a new point, *i.e.*, again from the end of the cathode rays.

Also for this reason the X-rays, which are not deflected by a magnet, cannot be regarded as cathode rays which have passed through the glass, for that passage cannot, according to Lenard, be the cause of the different deflection of the rays. Hence I conclude that the X-rays are not identical with the cathode rays, but are produced from the cathode rays at the glass surface of the tube.

(13) The rays are generated not only in glass. I have obtained them in an apparatus closed by an aluminium plate two mm. thick. I purpose later to investigate the behaviour of other substances.

(14) The justification of the term "rays," applied to the phenomena, lies partly in the regular shadow pictures produced by the interposition of a more or less permeable body between the source and a photographic plate or fluorescent screen.

I have observed and photographed many such shadow pictures. Thus, I have an outline of part of a door covered with lead paint; the image was produced by placing the discharge-tube on one side of the door, and the sensitive plate on the other. I have also a shadow of the bones of the hand (fig. 4), of a wire wound upon a bobbin, of a set of weights in a box, of a compass card and needle completely enclosed in a metal case (fig. 5), of a piece of metal where the X-rays show the want of homogeneity, and of other things.

For the rectilinear propagation of the rays, I have a pin-hole photograph of the discharge apparatus covered with black paper. It is faint but unmistakeable.

(15) I have sought for interference effects of the X-rays, but possibly in consequence of their small intensity, without result.

(16) Researches to investigate whether electrostatic forces act on the X-rays are begun but not yet concluded.

(17) If one asks, what then are these X-rays; since they are not cathode rays, one might suppose, from their power of exciting fluorescence and chemical action, them to be due to ultra-violet light. In opposition to this view a weighty set of considerations presents itself. If X-rays be indeed ultra-violet light, then that light must possess the following properties:—

(*a*) It is not refracted in passing from air into water, carbon bisulphide, aluminium, rock-salt, glass or zinc.

(*b*) It is incapable of regular reflection at the surfaces of the above bodies.

(*c*) It cannot be polarised by any ordinary polarising media.

(*d*) The absorption by various bodies must depend chiefly on their density.

That is to say, these ultra-violet rays must behave quite differently from the visible, infra-red, and hitherto known ultra-violet rays.

These things appear so unlikely that I have sought for another hypothesis.

A kind of relationship between the new rays and light rays appears to exist; at least the formation of shadows, fluorescence, and the production of chemical action point in this direction. Now it has been known for a long time, that besides the transverse vibrations which account for the phenomena of light, it is possible that longitudinal vibrations should exist in the ether, and, according to the view of some physicists, must exist. It is granted that their existence has not yet been made clear, and their properties are not experimentally demonstrated. Should not the new rays be ascribed to longitudinal waves in the ether?

I must confess that I have in the course of this research made myself more and more familiar with this thought, and venture to put the opinion forward, while I am quite conscious that the hypothesis advanced still requires a more solid foundation.

As a supplement to Professor Röntgen's paper we give a condensed report of Mr. A. A. C. Swinton's experiments, described also in *Nature* of the above date, and give reproductions of some of his results.

Mr. Swinton says that with the assistance of Mr. J. C. M. Stanton he repeated Röntgen's experiments with entire success. In one of their early experiments, an ordinary photographic plate was placed in the ordinary camera back, the sliding shutter made of wood kept closed, and on this such articles as coins, pieces of wood, carbon, ebonite, vulcanised fibre, aluminium, were placed, and above them a Crookes' tube, through which a current was allowed to pass for some minutes. On development, shadows of all objects were obtained, some proving more opaque than others. It may be noted here that the thickness of the wooden sliding shutter would be about a quarter of an inch. Working in this way, it was found that ebonite, vulcanised fibre, carbon, wood, cardboard, leather and slate, were all very transparent, whilst glass is very opaque. In fig. 3 is reproduced the shadowgram, because these results cannot be strictly called photograms, of a living human hand, taken through a sheet of aluminium ·0075 inches thickness, with an exposure of twenty minutes; and later experiments have shown that the necessary exposure can be reduced to four minutes by replacing the aluminium with black vulcanised rubber.

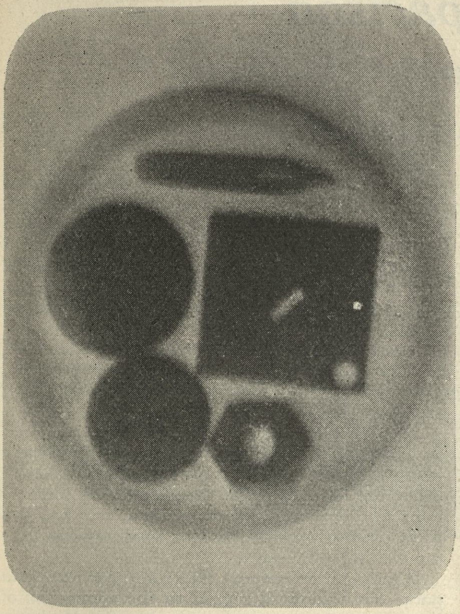

FIG. 10.—Metal objects in wooden box. Exposure four minutes.

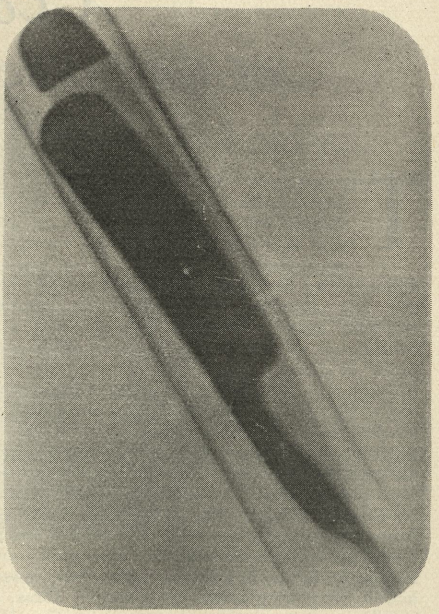

FIG. 11.—Razor closed, and in cardboard case. Exposure four minutes.

SHADOWGRAMS BY MR. CAMPBELL SWINTON.

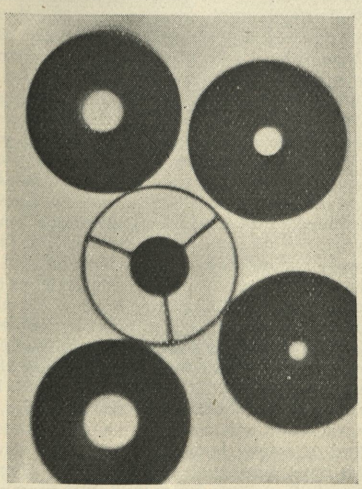

FIG. 12.—Metal discs through two sheets of cardboard and a sheet of aluminium. Aluminium between discs and plate. Exposure ten minutes.

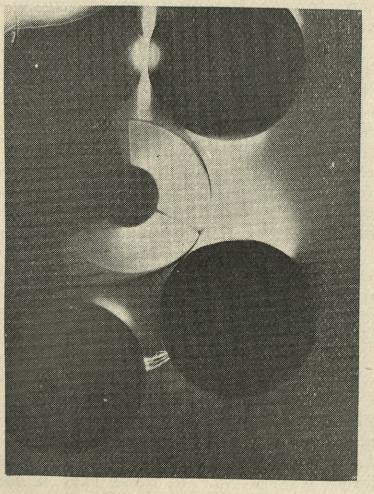

FIG. 13.—Shadowgram without Crookes' tube. Metal discs through cardboard box. Exposure ten minutes.

SHADOWGRAMS BY MR. J. W. GIFFORD.

A Comparison of Cathodic and "X-Rays."

By E. J. Wall, F.R.P.S.

The essential differences and similarities between the cathodic rays and Röntgen's X-rays will be well seen from his article, and also from the following facts, which summarise the facts: X-rays are not deflected by magnets, cathodic rays are; X-rays are not absorbed or diffused so readily as cathodic rays. X-rays will traverse several centimetres of wood, and several millimetres of metal or glass, while cathodic rays fail to pass through any but thin films of glass, aluminium, etc. The X-rays excite fluorescence, and gives shadowgrams at a distance of eighty inches from the tube, whilst the cathodic rays are absorbed or diffused at a distance of fifty inches. The cathode rays proceed from the cathode itself, whilst according to Röntgen, the X-rays do not proceed from the cathode, but from that part of the glass where the cathode rays strike. The main points of similarity between the two are their powerful action on photographically sensitive films, their rectilinear propagation as shown by the sharply defined shadows.

The discovery of these X-rays by Professor Röntgen was due, as is so often the case, entirely to an accident. He was experimenting with a Crookes' tube wrapped in an opaque material, and on his bench laid a piece of sensitive paper on which he found, after a powerful current had passed through the tube, that a black line had been formed on the paper. Keenly alive to all extraordinary phenomena, the learned professor proceeded to investigate, with the result of the discovery of what is practically something absolutely new, and the value of which we cannot at present appreciate. The subsequent developments may be of such a nature as to totally change our ideas of things in general.

Whilst the experiments hitherto made are from the utilitarian point of view of but little value, there is not the slightest doubt that in the near future they will be of considerable value, as has already been shown by Professor Mosetig, of Vienna, who obtained by this means shadowgrams of a man's hand, in which was embedded a bullet from a revolver, and also in the case of a girl who had a malformation of the foot. In both cases the exact location of the injury was obtained, and considerable assistance rendered to the surgeon. It will be possible, as here sketched out, to obtain not only the location of a foreign substance in the body, but possibly also valuable aid as to the displacement or injury to internal organs of the human body.

As it has been proved that metals possess a different transparency to these rays, it does not seem chimerical to assume that we have in these new rays a power to determine the perfect nature of an alloy for instance, or the presence or absence of flaws in castings in forgings, such as our heavy ordnance, etc.

It has been suggested that the time will come when it will be unsafe for anybody to walk through the streets because the amateur photographer, who is now armed with the hand-camera and requires daylight to obtain a result, will walk about armed with a small box or parcel enclosing his plate, and obtain shadowgrams of the bodies of those he meets through their clothes. But the absurdity of such a statement as this will be apparent when it is considered that the rays are, so far as is known, only produced by electric currents of very high tension.

From almost every part of the world confirmation of the correctness of Röntgen's discovery is pouring in, and it is now stated that Professor Silvanus Thompson has discovered that these X-rays are generated in the electric arc, and has been able to obtain excellent shadowgrams from the electric arc X-rays.

It may not be without interest to our readers to point out that with regard to the application of these rays for surgical purposes, Sir Benjamin Richardson, in 1868, read a paper before the British Association, at Norwich, on "The transmission of light through animal bodies," anent which the following passage occurs in the "Transactions."

> "The author exhibited a lamp which he had constructed for transmitting light through the structures of the animal body. He believed the first idea that such transmission could be effected was given in Priestley's work on Electricity. That great experimentalist, the Shakespeare of physical science, had observed, on passing a discharge of a Leyden battery through his finger, that the structure seemed to present luminosity, but the operation was extremely painful. The author had repeated this experiment with similar results. . . . In the human subject, especially in the young, having fragile tissues, the thinner parts of the body could be distinctly rendered transparent; and in a child, the bones, under a somewhat subdued light, could be seen in the arm and wrist. A fracture in a bone could, in fact, be easily made out, or growth from bone in these parts. In a very thin young subject, the movements and outline of the heart could also be faintly seen in the chest, but the light he had as yet employed had not been sufficiently powerful to render this demonstration all that he could desire. It would be possible, lastly, to see through some diseased structure, so as to ascertain whether, within a cavity, there was fluid or a solid body. . . . . The structure the most diaphanous was the skin; after that, singularly enough, bone; then thick membranes; next, thin superficial muscles, lung tissue, fat, and the dense tissues of the liver and the kidney. Various lights had been tried, viz.: the electric, oxyhydrogen, the lime light, and the magnesium. For all practical purposes the magnesium light

FIG. 14.—Lady's hand, with rings. Through cardboard and black vulcanite. Exposure, ten minutes.

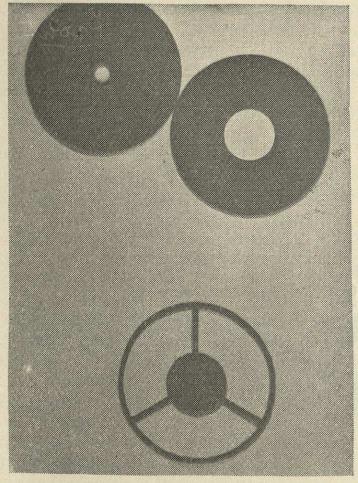

FIG. 15.—Metal discs through cardboard box placed in front of Crookes' tube; opposite cathode. Exposure, ten minutes.

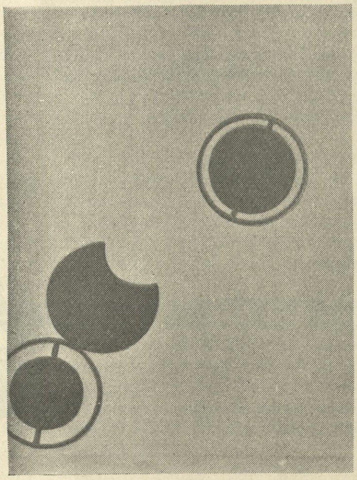

FIG. 16.—Metal discs through cardboard box placed at side of Crookes' tube. Exposure, ten minutes.

SHADOWGRAMS BY MR. J. W. GIFFORD.

was the best; it was the most convenient to use, and the light had the advantage of penetrating deeply."

It will at once be seen that this in nowise foreshadows Röntgen's valuable discovery.

To the technical expert we may point out that Mr. Swinton states that so far as his experiments have gone it appears that without very long exposures, a sufficiently active excitation of the Crookes' tube is not obtained by direct connection to an ordinary Rhumkorff induction coil, even of a large size. So-called high frequency currents, however, appear to give good results, and his experiments have been made with the tube excited by current obtained from the secondary circuit of a Tesla oil coil, through the primary of which were continuously discharged twelve half-gallon Leyden jars, charged by an alternating current of about 20,000 volts pressure, produced by a transformer with a spark-gap across its high-pressure terminals.

Dr. Neuhass, of Berlin, on the other hand, states that an induction coil which will give a spark of from four to six inches charged by a current of 20 ampères and 8 volts pressure may be used, but probably the difference of opinion is due to difference in length of exposure. The particular form of Crookes' tube, according to Mr. Swinton, does not matter much, although he cannot as yet say anything definite on this point, and suggests that part of the tube, at least, should be aluminium and not glass.

It may seem somewhat wonderful to talk of photographing invisible things, but this has been accomplished for many years, and is due to the fact that any light or other energy, although not visible, which is capable of so affecting the sensitive surface of a photographic plate exerts a certain action which is cumulative. A good example of this is seen in astro-photography. An observer may, at the first moment of observation, see, we will assume, 60 stars, but with longer gazing his retina gets tired and he sees less and less; on the other hand, the photographic retina or plate may see exactly the same number of stars at the first impact of light, but instead of getting tired it keeps on storing up the impressions, so that at the end of the first hour it will see 3600 times as much, and so on.

Although we cannot see a cannon ball or bullet in its flight, yet photograms or shadows of these have been obtained, and actually of the waves of air displaced by the bullet, and the air closing in behind the same. In fact, by photography, we have obtained permanent records of the head of air in front of, and the waves behind, as easily recognizable by the eye as the head of water driven in front of a big ship, and the eddy or swirl behind.

Of the detection of forgeries, &c., by photography we need hardly speak, but here the photographic plate recognizes distinct differences of the inks, &c., though the same be too minute to be detected by the eye.

The Work of Mr. J. W. Gifford.

NOTES BY H. SNOWDEN WARD, F.R.P.S.,

EDITOR OF *The Photogram*.

As soon as the first vague and somewhat contradictory reports of Professor Röntgen's work reached England, several independent investigators attempted to duplicate the results. The overwhelming number of requests for information made it impossible for Professor Röntgen to reply, except by a circular letter giving the name of the society's journal in which his original communication appeared. Difficulty in obtaining this publication, and no want of enterprise on the part of British investigators or technical journalists, somewhat delayed confirmation. So far as I can learn, several experimenters have absolutely failed to obtain results. Mr. J. W. Gifford, of Chard, who has done some valuable original work in photographic, electrical, and photomicrographic investigation, and who is fortunate in having an exceedingly well-appointed private laboratory, secured extremely interesting results. It seems probable that, owing to insufficient data in the early reports published in England, the cathode rays have far more to do than the X-rays with Mr. Gifford's results, but, from the point of view of "invisible light" they are none the less interesting. Mr. Gifford's results were shewn and outline particulars were given at the meeting of the Royal Photographic Society on January 21st; and by his kind invitation the writer of these notes took part in a fairly exhaustive series of confirmatory experiments. In these notes, therefore, the results of the two series are more or less blended.

Mr. Gifford is fortunate in being a gentleman of means and of reasonable leisure, and is specially fortunate in possessing a complete set of Crookes' vacuum tubes, which were used for the experiments and demonstrations of Mr. Crookes himself. The first series of experiments gave absolutely no result; though attempts were made, under varying conditions with each of the (five) tubes in turn. Taking up the work again, one of the tubes gave very good results, though the conditions (so far as is known) were the same as in some of the unsuccessful experiments. This tube was used in all the succeeding experiments, except where a vacuum tube was entirely dispensed with. It will be noted that there are two or three (as yet) unexplained failures. Even the definite results can only be regarded as preliminary, and the suggested explanations as tentative, and subject to considerable further investigation, which is proceeding.

In the whole of Mr. Gifford's experiments the photographic plates have been enclosed in cardboard boxes, so that one, or in some cases two thicknesses of brown cardboard (sometimes covered with a non-actinic red paper) have always been interposed between the source of the rays and the sensitive plate, in addition to any such substance as vulcanite, aluminium, &c., as is specifically mentioned. As the cardboard boxes are those in which the photographic dry-plate makers pack their plates for protection from light, they are perfectly impervious to ordinary actinic rays.

The apparatus consists of a powerful hand dynamo, attached to a ten-inch spark intensity coil, from the terminal standards of which the current was taken to the Crookes' tube. After the preliminary experiments, a uniform exposure of ten minutes was given to the plates, both when the tube was used and when it was dispensed with.

In the preliminary (successful) experiments a sheet of black vulcanite and the hand of a child were placed between the source of rays and the plate, with the result that an image of the hand was obtained, shewing that it partially obstructed the rays, but the distinction between bone and flesh was very slight indeed. Repeated experiments with varying exposures gave the same result, which led to the conclusion that it was caused by the fact that the child's bones were still semi-cartilaginous, and insufficiently ossified to secure contrast with the flesh. Later experiments with several adults confirmed this view, for the bones were fairly distinct. When the results by Mr. Campbell Swinton were published, their greater contrast between bones and flesh suggested further experiments. It was thought possible that the exposure might be in fault, but varying exposures gave no appreciable difference in result.

It was then suggested—which seems very probable (a few experiments will confirm or disprove it)—that the result was due to the comparatively large surface from which the rays were radiating and the comparative nearness of the object. This would give a penumbral effect, largely destroying the contrast. We have not seen Mr. Campbell Swinton's original negatives, so do not know to what extent the contrast in his results may be due to intensification in making the transparencies from which the illustrations are reproduced.

This leads us to say that the Crookes' tube used by Mr. Gifford is about four and a-half inches in diameter; that the hand was about one inch (and therefore the plate about two inches) from the front of the tube. In all other experiments with the tube the plate was placed about one inch from its surface.

Interposing discs of metal (blackened copper) between the plate and the vacuum tube, Mr. Gifford found that they obstructed the rays which passed freely through black vulcanite (about 1/12in. thick), through cardboard, and through aluminium (about 1/24in. thick) in sufficient force to produce a dense deposit of silver on development after a ten minutes' exposure.

It will be noted that Mr. Gifford places his Crookes' tube very near the receptacle containing the sensitive plate: it may therefore happen that he has actually been using cathade rays and not Röntgen's X-rays; but this in nowise detracts from the value of his results. One of the most interesting of his experiments is that in which the plate is placed opposite the anode, and parallel with the path of the cathode rays, and then obtained good results. This is strong support for the view expressed by Mr. Swinton, that the cathode rays are to a great extent absorbed by the glass, and that this absorption by the glass gives rise to X-rays.

As it had been stated that inorganic substances were impenetrable to the "X" and cathode rays, Mr. Gifford interposed a slab of earthenware, glazed on both sides, and about ¼in. thick, but found that through this a strong action was obtained.

Further, as it was suggested that the rays proceeded in direct lines from the cathode through the sides of the tube; and not from the surface of the tube itself, a plate was exposed behind metal discs, in front of the tube (opposite the cathode), and another at the side of the tube, its surface parallel with the main axis of the rays if proceeding, as suggested, in direct line from the cathode. The results, developed together, gave every sign of being equally exposed, and are reproduced in figs. 15 and 16.

Further experiments consisted of the use of anode, in place of cathode rays, in which case the same results were obtained.

In the course of the work several modifications in detail were made. In some cases the metal discs were in contact with the sensitive film of the plate. In some cases the glass of the plate itself interposed between the discs and the film. In other cases a sheet of alluminium separated the discs from the film. The only appreciable difference in these cases seems to be that when the discs are not in contact the outline of the image is less sharp, and there seems to be a slight "spreading" of the effect (see fig. 12.)

Turning from this series of experiments, Mr. Gifford tried whether similar rays were obtainable between plates of metal about 6in. apart, attached to the poles of the Apps' coil, the points of the coil being placed near enough for the sparking to take place between them only, not between the metal plates. The cardboard box containing the plate was stood up between them. The box contained the discs in contact with the film. The result was exceedingly peculiar, and gave rise to considerable discussion when shown at the Royal Photographic Society. There were four peculiar figures, similar to the one seen near the upper left-hand side of fig. 13, but no traces of the discs themselves. It was thought that the circular patches of deposit probably coincided with the central apertures in the pierced discs, and that the curious spreading effect was due to polarisation. The fact that three of the effects had parallel axes, while the fourth was at right angles, seemed to lend color to this, but later experiments suggest a totally different explanation.

The curious nature of this result caused Mr. Gifford to attempt to repeat it, but several attempts ended in failure, the plates showing no trace of light-action. A further experiment, in which the box containing the plate and discs in contact were placed immediately behind the sparking terminal of the Apps' coil, gave the result shewn in fig. 13, which seems to indicate that the metal discs become self-luminous by induction, and that the effect supposed to be due to polarisation is the result of a brush-like discharge of electricity between adjacent edges of the discs. In the case of two discs separated by a slightly greater distance the negative shews three distinct lines as of spark-discharge between the adjacent points, as well as several fainter spark-tracks.

The following abstract of an important paper by Herr G. Jaumann appeared in the issue of the the *Electrician* for Jan. 24th, and is worth consideration as bearing upon the subject:—

*Longitudinal Light.**

By G. JAUMANN.

In a paper published in 1888,† a law of discharges was enunciated, which has lately received striking confirmation, and which leads to important conclusions regarding the direction of vibration of cathode rays and light rays. Jaumann's law ran as follows: Vibrations of electric force, taking place at an electrode, and in a direction normal to it, have a specific favorable effect upon the discharge; but, in order to be perceptible, their amplitude must increase with their period. To a first approximation, the effect is proportional to the product of the amplitude into the vibration frequency, or, in other words, to the maximum rate of change of the electric force during the vibration. Since only such vibrations as take place perpendicularly to the surface of the electrode have any effect, the orientation of the source is of considerable influence. This has been verified by Wanka in the case of electric waves, and by Elster and Geitel in the case of light.‡

The arguments in favor of the view that the cathode rays are longitudinal electric oscillations are the following: In the first place, the cathode rays are strongest in the axis of symmetry of the discharge space. Their intensity is greatest there, and decreases outwards. Hence they are essentially longitudinal, although a radical or tangential transversality may be superposed.

The existence of longitudinal electric waves is not admitted by the Maxwell-Hertzian equations. But almost any change whatever made in them makes their existence possible. Now rarefied air has such a peculiar behaviour towards electric discharges that Maxwell's equations cannot possibly be regarded as adequate. The very fact of discharge contradicts them.

* Abstract from *Wied. Ann.*, No. 1, 1896, pp. 147-184.
† *Wien. Ber.*, 97, p. 765.

‡ *Wied. Ann.*, No. 52, p 440, 1894. *The Electrician.*

Experiments concerning the influence of the conducting wires upon cathode rays show that their vibration period is of the same order of magnitude as the waves in the wires—*i.e.*, something between 10^{-8} and 10^{-9} seconds. Hence they are not ultra-violet rays. If they were transverse, without being ultra-violet, they would be ordinary light or Hertzian waves. From these they are distinguished, however, by their totally different properties.

But the longitudinal nature of cathode rays may be proved by actual experiments, which have already been performed by Lenard. They were shown to have strong discharging influence when impinging normally upon the surface of the electrode. *Hence their direction of vibration coincides with their direction of propagation.*

Rarefied air has many peculiarities, owing to its small capacity for heat, *and other forms of energy*. The peculiar electric behaviour of air is due to the fact that electric actions indirectly change its magnetic and electric constants. But as soon as η and k are made variable in Maxwell's equations, longitudinal waves become possible.

The author works out new equations in accordance with these conditions, from which the existence of longitudinal rays follows as a matter of course. He also explains many of the peculiarities of discharged phenomena, such as the diffuse reflection of cathode rays by a plain smooth surface. This is due to the fact that Huyghens' principle becomes inapplicable when the direction of the cathode rays does not coincide with that of the statical electric force. He also explains the curvature of cathode rays in a magnetic field, and foreshadows the possible discovery of magnetic longitudinal waves. Herr Jaumann next shows that a limited cathode ray contains no transverse component along its axis, but that a radical electric and a tangential magnetic vibration sets in away from the axis, displaced by a quarter of a wave length from the original vibration. Conversely, he shows that transverse rays must always be blurred at the edges, and that even in ordinary air *longitudinal light, displaced by a quarter period, exists at the border of every pencil of transverse light.* This theoretical conclusion is completely substantiated by Elster and Geitel's work on the influence of the azimuth and angle of incidence of light upon liquid electrodes. In rarefied air the amplitude of the longitudinal vibration is about one-third of that of the transverse vibration.

As further results of importance come to hand, they will be added in later editions of this special issue; and the editors will be glad to receive early particulars, with examples of results, from any workers who may obtain results with novel features.

Mr. J. W. Gifford wishes us to say that he finds it quite impossible to answer the mass of unexpected correspondence on this subject, but that any communications he may be able to make to the press will be made through ourselves. Any communication received by us will be *at once* handed to the newsagencies; and for the convenience of journals that do not subscribe to the newsagencies, will be put into type immediately, and proof forwarded to such journals as have supplied us with stamped addressed envelopes for the purpose, and are willing to acknowledge source.

Our reproductions of Mr. Gifford's and Mr. Swinton's work are (by their author's kind permission) at the service of such journals as may wish to use them. We will supply hard-metal stereotypes from the original blocks, at a nominal price, on condition that the author and *The Photogram* be acknowledged.

LANTERN SLIDES of the work of Mr. CAMPBELL SWINTON are supplied by Newton and Co., 3 Fleet Street, London, price 2s. 6d. each. Our reproductions are made from some of these excellent slides. Mr. Gifford's results are supplied in lantern slide form, price 1s. 6d. each, by Chas. Baker, Optician, High Holborn, W.C.

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For the use of Prof. Röntgen's examples in producing our illustrations of his work, we are indebted to the Editor of *Nature*.